M.5.3.4 Immobilized Disposition Alternative for a Deep Borehole Complex

Studies of evaluation basis accidents and beyond evaluation basis accidents have been performed for a deep borehole immobilized disposal facility in the *Fissile Material Disposition Program: Deep Borehole Disposal Facility PEIS Data Input Report for Immobilized Disposal—Immobilized Disposal of Plutonium in Coated Ceramic Pellets in Grout Without Canisters.* The studies postulated a set of accidents scenarios that were representative of the risks and consequences for workers and the public that can be expected if the facility were constructed and operated. Although not all potential accidents were addressed, those that were postulated have consequences and risk that are expected to envelop the consequences and risks of an operating facility. In this manner, no other credible accidents with an expected frequency of occurrence larger than 1.0×10^{-7}/yr are anticipated that will have consequences and risks larger than those described in this section.

M.5.3.4.1 *Accident Scenarios and Source Terms*

A wide range of hazardous conditions and potential accidents were identified as candidates to represent the risks to workers and the public of operating the facility. Through a screening process, 14 evaluation basis accidents and 4 beyond evaluation basis accidents were selected for further definition and analysis. Descriptive information on these accidents is provided in Tables M.5.3.4.1–1 and M.5.3.4.1–2. Accident source term information is provided in Tables M.5.3.4.1–3 and M.5.3.4.1–4. Descriptions of accident scenarios are provided in Table M.5.3.4.1–5.

Table M.5.3.4.1–1. Evaluation Basis Accident Scenarios for Immobilized Disposition at the Deep Borehole Complex

Accident Scenario	Accident Frequency (per year)	Source Term at Risk	Source Term Released to Environment
Earthquake	1.0×10^{-6} to 1.0×10^{-4}	5 kg Pu	5.0×10^{-10} g Pu
Tornado	1.0×10^{-6} to 1.0×10^{-4}	NA	No release
Flood	1.0×10^{-6} to 1.0×10^{-4}	NA	No release
Pu storage container breakage	1.0×10^{-4} to 0.01	5 kg Pu	5.0×10^{-12} g Pu
Pu storage container breach	1.0×10^{-4} to 0.01	5 kg Pu	5.0×10^{-12} g Pu
Onsite pellet transporter accident	1.0×10^{-4} to 0.01	5 kg Pu	No release
Pellet-grout mixing process facility fire	1.0×10^{-6} to 1.0×10^{-4}	5 kg Pu	5.0×10^{-10} g Pu
Ceramic pellet spill	1.0×10^{-4} to 0.01	0.5 kg Pu	5.0×10^{-13} g Pu
Pellet-grout mix spill	0.01 to 0.1	0.5 kg Pu	3.0×10^{-11} g Pu
Failure of ventilation blower	0.01 to 0.1	NA	No release
Loss of electrical power	0.01 to 0.1	NA	No release
Bucket Emplacement			
Bucket dropped during emplacement	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	5.0×10^{-7} g Pu
Bucket stuck in the isolation zone	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	No release
Bucket stuck in emplacement zone	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	No release
Failure of release—fails to open	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	No release
Failure of release—opens early during bucket emplacement	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	2.5×10^{-6} g Pu
Pellet-grout sets in bucket	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	No release
Mixing system breaks pellets during bucket emplacement	1.0×10^{-4} to 0.01	834 kg Pu	5.0×10^{-8} g Pu
Pellets break during bucket emplacement release	1.0×10^{-4} to 0.01	834 kg Pu	5.0×10^{-8} g Pu
Emplacement facility fire - combustibles	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	No release
Emplacement facility fire - electrical	1.0×10^{-6} to 1.0×10^{-4}	834 kg Pu	No release
Loss of electrical power	0.01 to 0.1	NA	No release
Pumped Emplacement			
Rupture of delivery pipe during pumped emplacement	1.0×10^{-6} to 1.0×10^{-4}	100 kg Pu	3.0×10^{-7} g Pu
Pellet-grout solidifies in delivery pipe	1.0×10^{-4} to 0.01	100 kg Pu	No release
Delivery pipe dropped during pumped emplacement	1.0×10^{-6} to 1.0×10^{-4}	100 kg Pu	6.0×10^{-8} g Pu
Delivery pipe stuck in the borehole	$<1.0\times10^{-6}$	100 kg Pu	No release
Mixing system breaks pellets during pumped emplacement	1.0×10^{-4} to 0.01	100 kg Pu	6.0×10^{-9} g Pu
Pellets break during release during pumped emplacement	1.0×10^{-4} to 0.01	100 kg Pu	6.0×10^{-9} g Pu

Table M.5.3.4.1–1. Evaluation Basis Accident Scenarios for Immobilized Disposition at the Deep Borehole Complex—Continued

Accident Scenario	Accident Frequency (per year)	Source Term at Risk	Source Term Released to Environment
Emplacement facility fire—combustibles	$1.0x10^{-6}$ to $1.0x10^{-4}$	100 kg Pu	No release
Emplacement facility fire—electrical	$1.0x10^{-6}$ to $1.0x10^{-4}$	100 kg Pu	No release
Loss of electrical power	0.01 to 0.1	NA	No release

Note: NA=not applicable.

Source: LLNL 1996h.

Table M.5.3.4.1–2. Beyond Evaluation Basis Accident Scenarios for Immobilized Disposition at the Deep Borehole Complex

Accident Scenario	Accident Frequency (per year)	Source Term at Risk	Source Term Released to Environment
Failure of ventilation filter	$<1.0x10^{-6}$	0.5 kg Pu	$3.0x10^{-9}$ g Pu
Uncontrolled chemical reaction	$<1.0x10^{-6}$	5 kg Pu	$5.0x10^{-9}$ g Pu
Pellet storage nuclear criticality	$<1.0x10^{-6}$	$1.0x10^{19}$ prompt fissions in 8 hrs; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen	[a]
Pellet-grout mixing nuclear criticality	$<1.0x10^{-6}$	$1.0x10^{19}$ prompt fissions in 8 hrs; noble gas and halogen fission products release. Release factors: 1.0 noble gas, 0.25 halogen.	[a]

[a] See Table M.5.3.4.1–4.

Source: LLNL 1996h.

Table M.5.3.4.1–3. Immobilized Disposition at the Deep Borehole Complex Evaluation Basis Accident Source Terms

Accident Parameter	Accident Scenario						
	Earthquake	Pu Storage Container Breakage	Pu Storage Container Breach	Pellet-Grout Mixing Process Facility Fire	Ceramic Pellet Spill	Pellet-Grout Mix Spill	Dropped Bucket During Emplacement
Frequency of occurrence (per year)	1.0×10^{-5}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-5}	1.0×10^{-3}	0.05	1.0×10^{-5}
Pu released to environment (g)	5.0×10^{-10}	5.0×10^{-12}	5.0×10^{-12}	5.0×10^{-10}	5.0×10^{-13}	3.0×10^{-11}	5.0×10^{-7}
Isotope Released to Environment (Ci)							
Pu-238	7.90×10^{-13}	7.90×10^{-15}	7.90×10^{-15}	7.90×10^{-13}	7.90×10^{-16}	4.74×10^{-14}	7.90×10^{-10}
Pu-239	2.86×10^{-11}	2.86×10^{-13}	2.86×10^{-13}	2.86×10^{-11}	2.86×10^{-14}	1.72×10^{-12}	2.86×10^{-8}
Pu-240	7.60×10^{-12}	7.60×10^{-14}	7.60×10^{-14}	7.60×10^{-12}	7.60×10^{-15}	4.56×10^{-13}	7.60×10^{-9}
Pu-241	2.69×10^{-11}	2.69×10^{-13}	2.69×10^{-13}	2.69×10^{-11}	2.69×10^{-14}	1.62×10^{-12}	2.69×10^{-8}
Pu-242	1.11×10^{-15}	1.12×10^{-17}	1.12×10^{-17}	1.11×10^{-15}	1.12×10^{-18}	6.69×10^{-17}	1.12×10^{-12}
Am-241	1.42×10^{-13}	1.42×10^{-15}	1.42×10^{-15}	1.42×10^{-13}	1.42×10^{-16}	8.52×10^{-15}	1.42×10^{-10}

Table M.5.3.4.1–3. Immobilized Disposition at the Deep Borehole Complex Evaluation Basis Accident Source Terms—Continued

Accident Parameter	Accident Scenario						
	Failure of Release - Opens Early During Bucket Emplacement	Mixing System Breaks Pellets During Bucket Emplacement	Pellets Break During Bucket Emplacement Release	Rupture of Delivery Pipe During Pumped Emplacement	Delivery Pipe Dropped During Pumped Emplacement	Mixing System Breaks Pellets During Pumped Emplacement	Pellets Break During Pumped Emplacement Release
Frequency of occurrence[a](per year)	1.0×10^{-5}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-5}	1.0×10^{-5}	1.0×10^{-3}	1.0×10^{-3}
Pu released to environment (g)	2.5×10^{-6}	5.0×10^{-8}	5.0×10^{-8}	3.0×10^{-7}	6.0×10^{-8}	6.0×10^{-9}	6.0×10^{-9}
Isotope Released to Environment (Ci)							
Pu-238	3.95×10^{-9}	7.90×10^{-11}	7.90×10^{-11}	4.74×10^{-10}	9.48×10^{-11}	9.48×10^{-12}	9.48×10^{-12}
Pu-239	1.43×10^{-7}	2.86×10^{-9}	2.86×10^{-9}	1.72×10^{-8}	3.43×10^{-9}	3.43×10^{-10}	3.43×10^{-10}
Pu-240	3.80×10^{-8}	7.60×10^{-10}	7.60×10^{-10}	4.56×10^{-9}	9.12×10^{-10}	9.12×10^{-11}	9.12×10^{-11}
Pu-241	1.35×10^{-7}	2.70×10^{-9}	2.70×10^{-9}	1.62×10^{-8}	3.23×10^{-9}	3.23×10^{-10}	3.23×10^{-10}
Pu-242	5.58×10^{-12}	1.12×10^{-13}	1.12×10^{-13}	6.69×10^{-13}	1.34×10^{-13}	1.34×10^{-14}	1.34×10^{-15}
Am-241	7.10×10^{-10}	1.42×10^{-11}	1.42×10^{-11}	8.52×10^{-11}	1.70×10^{-11}	1.70×10^{-12}	1.70×10^{-12}

[a]Midpoint of the estimated frequency range.

Note: Am=Americium.

Source: Derived from Tables M.5.1.3.4–1 and M.5.3.4.1–1.

Table M.5.3.4.1–4. Immobilized Disposition at the Deep Borehole Complex Beyond Evaluation Basis Accident Source Terms

Accident Parameter	Accident Scenario			
	Failure of Ventilation Filter	Uncontrolled Chemical Reaction	Pellet Storage Nuclear Criticality[a]	Pellet-Grout Mixing Process Nuclear Criticality
Frequency of occurrence (per year)	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}
Pu released to environment (g)	3.0×10^{-9}	5.0×10^{-9}	NA	NA
Fissions	NA	NA	1.0×10^{19}	1.0×10^{19}
Isotope Released to Environment (Ci)				
Pu-238	4.74×10^{-12}	7.90×10^{-12}	0	0
Pu-239	1.72×10^{-10}	2.86×10^{-10}	0	0
Pu-240	4.56×10^{-11}	7.60×10^{-11}	0	0
Pu-241	1.62×10^{-10}	2.70×10^{-10}	0	0
Pu-242	6.69×10^{-15}	1.12×10^{-14}	0	0
Am-241	8.52×10^{-13}	1.42×10^{-12}	0	0
Kr-83m	0	0	110	110
Kr-85m	0	0	71	71
Kr-85	0	0	8.1×10^{-4}	8.1×10^{-4}
Kr-87	0	0	430	430
Kr-88	0	0	230	230
Kr-89	0	0	1.3×10^{-4}	1.3×10^{-4}
Xe-131m	0	0	0.1	0.1
Xe-133m	0	0	2.2	2.2
Xe-133	0	0	27	27
Xe-135m	0	0	3.3×10^{3}	3.3×10^{3}
Xe-135	0	0	410	410
Xe-137	0	0	4.9×10^{4}	4.9×10^{4}
Xe-138	0	0	1.1×10^{4}	1.1×10^{4}
I-131	0	0	2.75	2.75
I-132	0	0	300	300
I-133	0	0	40	40
I-134	0	0	1.08×10^{3}	1.08×10^{3}
I-135	0	0	113	113

[a] Curies produced (by isotope) for the 1.0×10^{19} fission criticality were scaled from Table M.5.3.1.1–3.

Note: NA=not applicable.

Source: Derived from Tables M.5.1.3.4–1, M.5.3.1.1–3, and M.5.3.4.1–2.

Table M.5.3.4.1–5. Accident Scenario Descriptions for Immobilized Disposition at the Deep Borehole Complex

Accident Scenario	Accident Description
Evaluation Basis Accidents	
Earthquake	It was postulated that the evaluation basis earthquake would rupture the ceramic pellet grouting vessel and lines. The Pu-containing particulate would be removed from the grouting area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Pu storage container breakage	It is postulated that a container breakage could occur in ceramic pellet storage. Respirable fines of ceramic are released to the storage area and collected by the ventilation system. The airborne fines pass through the ventilation HEPA filters and are released to the environment.
Pu storage container breach	It is postulated that a container breach could occur in ceramic pellet container handling operations. A container is punctured during handling and ceramic pellets spill from the punctured container. Respirable fines of ceramic are released to the process area and collected by the ventilation system. The airborne fines pass through the ventilation HEPA filters and are released to the environment.
Pellet-grout mixing process facility fire	It is postulated that an unimpeded fire begins in the process area which houses the grouting vessel. The fire breaches the vessel enclosure that contains the Pu-loaded ceramic pellets. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Ceramic pellet spill	It is postulated that the ceramic pellets overflow the grouting feed bin and spill onto the floor. The spill spreads out in a safe geometry. The spill is cleaned up in two hours but some of the spill material converts to an aerosol and becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Pellet-grout mix spill	It is postulated that the grouting vessel or the bucket overflows and spills onto the floor. The spill spreads out in a safe geometry. The spill is cleaned up in 2 hours but some of the spill material converts to an aerosol and becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Dropped bucket during emplacement	A bucket could be dropped into the borehole as a result of either a structural failure in the crane, the associated hoisting and securing equipment, or as a result of operator error. A free-falling bucket could rupture upon impact at the bottom of the borehole.
Failure of release—opens early during bucket emplacement	The valve at the bottom of the bucket opens prematurely and the pellets and the cement free fall to the bottom of the borehole. This would probably result in some broken or fractured pellets.
Mixing system breaks pellets during emplacement	The pellets are mixed with cement and pushed with water, air pressure, or gravity into the bucket. It is postulated that some of the pellets may break or crack due to unforeseen events in the emplacement process.
Pellets break during bucket emplacement release	Upon release, the pellets and cement will flow out into the borehole. The weight of the column in the bucket and the pressure that will likely be needed to push out the mix could cause some of the pellets to break due to some unforeseen events in the emplacement process.
Rupture of delivery pipe during pumped emplacement	If the delivery pipe were to rupture, the pellets and cement would free fall to the bottom of the borehole. This would probably result in some broken or fractured pellets.

Table M.5.3.4.1–5. Accident Scenario Descriptions for Immobilized Disposition at the Deep Borehole Complex—Continued

Accident Scenario	Accident Description
Delivery pipe dropped during pumped emplacement	A delivery pipe could be dropped into the borehole as a result of either a structural failure in the crane or drill rig, or as a result to operator error. Substantial quantities of ceramic pellets could be broken or cracked upon impact at the bottom of the borehole.
Mixing system breaks pellets during pumped emplacement	The pellets are mixed with cement and pushed with water, air pressure, or gravity into the delivery pipe. It is postulated that some of the pellets may break or crack due to unforeseen events in the process.
Pellets break during pumped emplacement release	Upon release from the end of the delivery pipe, the pellets and cement will flow out into the borehole. The weight of the column in the pipe and the pressure that will likely be needed to push out the mix could cause some of the pellets to break due to some unforeseen events in the emplacement process.
Beyond Evaluation Basis Accidents	
Failure of ventilation filter	A HEPA filter could fail due to moisture collection on the filter, excessive pressure loading from exhaust blower, excessive heat from a fire, or mechanical shock. It is postulated that the HEPA filter servicing the grout mixing process fails concurrently with a grouting process spill accident. Some of the spill material converts to an aerosol and becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system, pass through the failed HEPA filters and be released to the environment.
Uncontrolled chemical reaction	It is postulated that hydrogen produced in the battery of the uninterruptible power system detonates in the grout mix vessel area, fractures pellets in the process, and some of the fractured pellets becomes airborne as respirable particles. The Pu-containing particulate would be removed from the process area by the ventilation system. The particulate then passes through a HEPA filtration system before it is released to the environment.
Pellet storage nuclear criticality	The designed Pu concentration in the ceramic pellet is sufficiently low to maintain criticality safe under all postulated accidents and natural conditions. The facility is designed to preclude flooding in the storage area. A nuclear criticality accident in the pellet storage vault area is not credible. However, a criticality accident was postulated, and the assumed criticality accident severity is based on guidance provided in NRC Regulatory Guide 3.35.
Pellet-grout mixing process nuclear criticality	The designed Pu concentration in the ceramic pellet is sufficiently low to maintain criticality safe under all postulated accidents during grout mixing process conditions. A nuclear criticality accident in the pellet storage vault area is not credible. However, a criticality accident was postulated, and the assumed criticality accident severity is based on guidance provided in NRC Regulatory Guide 3.35.

Source: LLNL 1996a.

M.5.3.4.2 *Accident Impacts*

The estimated range of impacts of the postulated accidents at reference sites are provided in Table M.5.3.4.2–1. The estimated range of environmental data (wet to dry site) and the general public population density data (low to high density) for the reference sites envelop the site characteristics expected for the emplacement site. The dose and cancer fatality estimates are based on the analysis of the accident source terms in Tables M.5.3.4.1–3 and M.5.3.4.1–4 using the MACCS computer code.

[Text deleted.]

Table M.5.3.4.2–1. Immobilized Disposition at the Deep Borehole Complex Accident Impacts Ranges at Generic Site

	Worker at 1,000 m				Maximum Offsite Individual				Population to 80 km				
	Dose (rem)		Probability of Cancer Fatality[a]		Dose (rem)		Probability of Cancer Fatality[a]		Dose (person-rem)		Number of Cancer Fatalities[b]		Accident Frequency (per year)
Accident Scenario	High	Low	High	Low	High	Low	High	Low	High	High	Low	Low	
Earthquake	1.4×10^{-10}	5.8×10^{-11}	5.7×10^{-14}	2.3×10^{-14}	2.3×10^{-11}	1.0×10^{-12}	1.2×10^{-14}	$5./2\times10^{-16}$	2.0×10^{-8}	1.9×10^{-10}	1.0×10^{-11}	9.3×10^{-14}	1.0×10^{-5}
Pu storage container breakage	1.4×10^{-12}	5.8×10^{-13}	5.7×10^{-16}	2.3×10^{-16}	2.3×10^{-13}	1.0×10^{-14}	1.2×10^{-16}	5.2×10^{-18}	2.0×10^{-10}	1.9×10^{-12}	1.0×10^{-13}	9.3×10^{-16}	1.0×10^{-3}
Pu storage container breach	1.4×10^{-12}	5.8×10^{-13}	5.7×10^{-16}	2.3×10^{-16}	2.3×10^{-13}	1.0×10^{-14}	1.2×10^{-16}	5.2×10^{-18}	2.0×10^{-10}	1.9×10^{-12}	1.0×10^{-13}	9.3×10^{-16}	1.0×10^{-3}
Pellet-grout mixing process facility fire	1.4×10^{-10}	5.8×10^{-11}	5.7×10^{-14}	2.3×10^{-14}	2.3×10^{-11}	1.0×10^{-12}	1.2×10^{-14}	5.2×10^{-16}	2.0×10^{-8}	1.9×10^{-10}	1.0×10^{-11}	9.3×10^{-14}	1.0×10^{-5}
Ceramic pellet spill	1.4×10^{-13}	5.8×10^{-14}	5.7×10^{-17}	2.3×10^{-17}	2.3×10^{-14}	1.0×10^{-15}	1.2×10^{-17}	5.2×10^{-19}	2.0×10^{-11}	1.9×10^{-13}	1.0×10^{-14}	9.3×10^{-17}	1.0×10^{-3}
Pellet grout mix spill	8.5×10^{-12}	3.4×10^{-12}	3.4×10^{-15}	1.4×10^{-15}	1.4×10^{-12}	6.2×10^{-14}	6.9×10^{-16}	3.1×10^{-17}	1.2×10^{-9}	1.1×10^{-11}	6.0×10^{-13}	5.5×10^{-15}	5.0×10^{-2}
Bucket dropped during emplacement	1.4×10^{-7}	5.8×10^{-8}	5.7×10^{-11}	2.3×10^{-11}	2.3×10^{-8}	1.0×10^{-9}	1.2×10^{-11}	5.2×10^{-13}	2.0×10^{-5}	1.9×10^{-7}	1.0×10^{-8}	9.3×10^{-11}	1.0×10^{-5}
Failure of release - opens early during bucket emplacement	7.1×10^{-7}	2.8×10^{-7}	2.8×10^{-10}	1.1×10^{-10}	1.2×10^{-7}	5.1×10^{-9}	5.8×10^{-11}	2.6×10^{-12}	1.0×10^{-4}	$9.1\times10x^{-7}$	5.0×10^{-8}	4.6×10^{-10}	1.0×10^{-5}
Mixing system breaks pellets during emplacement	1.4×10^{-8}	5.8×10^{-9}	5.7×10^{-12}	2.3×10^{-12}	2.3×10^{-9}	1.0×10^{-10}	1.2×10^{-12}	5.2×10^{-14}	2.0×10^{-6}	1.9×10^{-8}	1.0×10^{-9}	9.3×10^{-12}	1.0×10^{-3}
Pellets break during bucket emplacement release	1.4×10^{-8}	5.8×10^{-9}	5.7×10^{-12}	2.3×10^{-12}	2.3×10^{-9}	1.0×10^{-10}	1.2×10^{-12}	5.2×10^{-14}	2.0×10^{-6}	1.9×10^{-8}	1.0×10^{-9}	9.3×10^{-12}	1.0×10^{-3}

Table M.5.3.4.2–1. Immobilized Disposition at the Deep Borehole Complex Accident Impacts Ranges at Generic Site—Continued

	Worker at 1,000 m				Maximum Offsite Individual				Population to 80 km				
	Dose (rem)		Probability of Cancer Fatality[a]		Dose (rem)		Probability of Cancer Fatality[a]		Dose (person-rem)		Number of Cancer Fatalities[b]		Accident Frequency (per year)
Accident Scenario	High	Low	High	Low	High	Low	High	Low	High	High	Low	Low	
Rupture of delivering pipe during pumped emplacement	8.5×10^{-8}	3.4×10^{-8}	3.4×10^{-11}	1.4×10^{-11}	1.4×10^{-8}	6.2×10^{-10}	7.2×10^{-12}	3.1×10^{-13}	1.2×10^{-5}	1.1×10^{-7}	6.0×10^{-9}	5.5×10^{-11}	1.0×10^{-5}
Delivering pipe dropped during pumped emplacement	1.7×10^{-8}	6.9×10^{-9}	6.8×10^{-12}	2.7×10^{-12}	2.8×10^{-9}	1.2×10^{-10}	1.4×10^{-12}	6.2×10^{-14}	2.4×10^{-6}	2.2×10^{-8}	1.2×10^{-9}	1.1×10^{-11}	1.0×10^{-5}
Mixing system breaks pellets during pumped emplacement	1.7×10^{-9}	6.9×10^{-10}	6.8×10^{-13}	2.7×10^{-13}	2.8×10^{-10}	1.2×10^{-11}	1.4×10^{-13}	6.2×10^{-15}	2.4×10^{-7}	2.2×10^{-9}	1.2×10^{-10}	1.1×10^{-12}	1.0×10^{-3}
Pellets break during pumped emplacement release	1.7×10^{-9}	6.9×10^{-10}	6.8×10^{-13}	2.7×10^{-13}	2.8×10^{-10}	1.2×10^{-11}	1.4×10^{-13}	6.2×10^{-15}	2.4×10^{-7}	2.2×10^{-9}	1.2×10^{-10}	1.1×10^{-12}	1.0×10^{-3}
Failure of ventilation filter	8.5×10^{-10}	3.4×10^{-10}	3.4×10^{-13}	1.4×10^{-13}	1.4×10^{-10}	6.2×10^{-12}	6.9×10^{-14}	3.1×10^{-15}	1.2×10^{-7}	1.1×10^{-9}	6.0×10^{-11}	5.5×10^{-13}	1.0×10^{-6}
Uncontrolled chemical reaction	1.4×10^{-9}	5.8×10^{-10}	5.7×10^{-13}	2.3×10^{-13}	2.3×10^{-10}	1.0×10^{-11}	1.2×10^{-13}	5.2×10^{-15}	2.0×10^{-7}	1.9×10^{-9}	1.0×10^{-10}	9.3×10^{-13}	1.0×10^{-6}
Pellet storage nuclear criticality	3.5×10^{-2}	1.6×10^{-2}	1.4×10^{-5}	6.2×10^{-6}	5.8×10^{-3}	2.0×10^{-4}	2.9×10^{-6}	1.0×10^{-7}	1.3	6.6×10^{-3}	6.3×10^{-4}	3.3×10^{-6}	1.0×10^{-6}
Pellet-grout mixing nuclear criticality	3.5×10^{-2}	1.6×10^{-2}	1.4×10^{-5}	6.2×10^{-6}	5.8×10^{-3}	2.0×10^{-4}	2.9×10^{-6}	1.0×10^{-7}	1.3	6.6×10^{-3}	6.3×10^{-4}	3.3×10^{-6}	1.0×10^{-6}

[a] Increased likelihood (or probability) of cancer fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

[b] Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Source: Calculated using the source terms in Tables M.5.3.3.1–3 and M.5.3.3.1–4 and the MACCS computer code.